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While Waiting on the LOS-F-H, Should We Replace PIVADS with the Bradley?

A Monograph
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First Term 90-91

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	24/12/90	Monograph

4. TITLE AND SUBTITLE
While Waiting on the LOS-F-H, Should We Replace PIVADS with the Bradley?

5. FUNDING NUMBERS

6. AUTHOR(S)
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7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
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8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for Public Release; Distribution Unlimited

12b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 words)

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14. SUBJECT TERMS				15. NUMBER OF PAGES
Product Improved Vulcan Air Defense System			Vulcan	54
Short Range Air Defense	Bradley	BFV	PIVADS	16. PRICE CODE
Bradley Fighting Vehicle	Air Defense Guns		SHORAD	

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	Unlimited

SCHOOL OF ADVANCED MILITARY STUDIES

MONOGRAPH APPROVAL

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Accepted this 11th day of February 1991

ABSTRACT

While Waiting on the LOS-F-H, Should We Replace PIVADS with the Bradley? by Jack E. Faires, USA, 54 pages.

This monograph addresses a pertinent doctrinal question which must be considered before making a decision to replace the Product Improved Vulcan Air Defense System with the Bradley Fighting Vehicle. The purpose is to establish a starting point for discussion. The basis is doctrine as outlined in FM 100-5, Operations.

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PRELUDE - THEORY AND CONCEPTS

The famous Italian theorist, Giulio Douhet, was one of the first prophets of the utility of air superiority. Many of his ideas on the use of air power are still valid and practiced today. These include the adoption of independent air forces[1], the emphasis on bomber and air combat units[2], the offensive role of air power[3], and the rationale of destroying enemy aircraft while still on the ground.[4] He postulated that planes moved too fast, were too difficult to detect, and could be launched against too many targets for the possibility of an effective, wide-ranging air defense.[5] Although Douhet was not precise on all of his predictions, he should receive credit for forecasting the difficulty in providing a persuasive ground-based air defense.

To confront the problem of protecting oneself from enemy control of the battlefield's third dimension (air), both the United States and the Soviet Union have adopted a three-tiered operational concept of providing air defense. The first objective is for friendly aircraft to destroy enemy aircraft on the ground. The second is to devote fighter aircraft to defeat the enemy in the air. The third is to devise ground-based air defense systems to protect high-value assets from enemy air attack. It is this third phase - the attempt to support the operational concept with ground based air defense systems -- that is the general topic of this monograph.

INTRODUCTION

Supporting the concept of ground-based air defense, the United States Army has several air defense systems currently fielded. All except one are missile systems. The lone gun system is the Product Improved Vulcan Air Defense System (PIVADS). Its 20 mm cannon, mounted on a modified M113 chassis, is scheduled to be phased out of the active inventory and replaced by the Line of Sight-Forward-Heavy (LOS-F-H) air defense / anti-armor system (ADATS). The LOS-F-H is initially configured only to carry missiles. This depletes the active inventory of any air defense specific gun systems.

As of this writing, the LOS-F-H air defense system is scheduled to be funded for production with fielding in the later part of the decade. With the inherent technical, political, and economic uncertainties that accompany the research, development, and appropriations for new weapons systems[6], the question arises as to whether the United States Army should replace the PIVADS with the Bradley Fighting Vehicle (BFV) in all of its heavy divisions.

This is not a new idea. The BFV's ability to fire in the air defense mode has been known since its development.[7] Due to funding constraints and fielding timelines, the emphasis has always been to put the Bradley's where they are needed most -- with the mechanized infantry. There are, however, numerous heavy-division force structure reductions currently being contemplated. These reductions may result in the availability of excess BFVs -- which could replace the PIVADS. The PIVADS, however, is specifically designed for the short range air defense (SHORAD) role. What are the advantages of

one system over the other in providing air defense for forward maneuver units?

This monograph will address a pertinent doctrinal question which must be considered before making a decision to replace a weapon system. The purpose here is to establish a starting point for discussion. The basis is tactical doctrine as outlined in FM 100-5, Operations. The specific question is -- which system is more capable of applying the dynamics of combat power (maneuver, firepower, protection and leadership) on the modern battlefield?

The above question will be analyzed in the context of the priority missions of SHORAD weapons systems. *I will use these priority missions to serve as the criteria in determining which system is more capable of applying the dynamics of combat power on the modern battlefield.* The priority SHORAD missions are protecting the force, providing the force with freedom to maneuver and denying the enemy sanctuary in the main battle area.

In Chapter one I will evaluate maneuver. The evaluation criterion is freedom to maneuver. Specifically, which system is more capable of performing the SHORAD mission of providing forces in the main battle area with freedom to maneuver? Many comparisons will be made between PIVAD and the BFV. Most of these comparisons will be technical in nature, such as maximum speeds and operational ranges. Also highlighted in chapter one will be a brief discussion of the need for a dedicated air defense unit for maneuver forces.

In Chapter two I will discuss firepower. Which system is more capable of performing the SHORAD mission of denying the enemy sanctuary in the main battle area? Again, many technical parameters

will be analyzed, such as volume of fire and maximum effective ranges. The chapter will end with an assessment of the current and future need for a gun system in the air defense role.

Chapter three discusses protection. Which system is more capable of performing the SHORAD mission of protecting the force? Protection is viewed in two contexts. First is the inherent protection for air defense units from direct and indirect fires. Second is the air defense protection provided to forward units operating in the main battle area. As with previous chapters, the argument will be mostly a technical comparison between the BFV and PIVADS systems.

Finally, in chapter four, the aspect of leadership will be addressed. Leadership encompasses the human element. Therefore, chapter four will adopt a different approach for comparisons between the systems. There will be less emphasis on technical comparisons and more emphasis on reviewing the different levels of leadership challenges when considering either weapon system. Specifically, what is the projected effect of battle on soldiers, units and leaders utilizing the two different systems? Several issues will be raised. All will be discussed within the context of the other dynamics of combat power -- maneuver, firepower and protection.

One must not lose sight that the air defense community is dedicated to the acquisition of the LOS-F-H system. The initial version of the LOS-F-H is a missile system mounted on a Bradley chassis.[8] It carries an acquisition radar and is capable of IFF (Identification, Friend or Foe) interrogation. The radar can scan for targets out to about 24 kilometers and to altitudes of around 20,000 feet. It is capable of searching while the prime mover is traveling.[9] The system carries eight ground-to-

ground/ground-to-air laser-guided missiles.[10] Each has a maximum effective range in excess of eight kilometers against aircraft or armor targets.[11] Neither the BFV nor the PIVADS offers this magnitude of air defense (or anti-armor) capability.

The acquisition and fielding of the LOS-F-H should proceed as soon as practical. This monograph postulates an interim change only and is directed at analyzing the potential for a short-term improvement in air defense capability within the heavy division. This being the case, we must weigh any decision (either to adopt the BFV or retain the PIVADS) against the long-term prospect of either interrupting or delaying the fielding of the LOS-F-H system.

CHAPTER 1 -- MANEUVER

On 7 March, 1945, retreating German forces failed to destroy the Ludendorff Bridge crossing the Rhine river at the city of Remagen. Within 24 hours, over 8000 U.S. soldiers crossed to the east side into the heart of Germany. During the next several days the German air force flew 442 sorties against the Remagen bridgehead. U.S. anti-aircraft guns shot down 142 confirmed kills and claimed an additional 59 probables. The bridgehead was successfully defended from aerial attack. After 13 days, the Luftwaffe ceased attempting to enter the Remagen area.[12]

Movement to achieve positional advantage over the opponent defines maneuver.[13] Tactical maneuver attempts to establish the terms of combat in a battle or engagement.[14] One primary mission of SHORAD units is to provide freedom of maneuver in order to seize and retain the initiative.[15] The air defense of the bridge at Remagen is an excellent example of this. To accomplish their mission, air defense units employed with the forward maneuver units must have some inherent degree of maneuverability.

When comparing the maneuver ability of the Bradley and the PIVADS systems, many parameters arise for analysis. This chapter will limit these to the three most prominent. The first two compare the overall performance characteristics and maneuverability during night or limited visibility operations. The third category addresses the need for dedicated air defense units performing the primary SHORAD mission in the division main battle area.

PERFORMANCE CHARACTERISTICS - MANEUVER

The Bradley Fighting Vehicle was designed and constructed to provide transport, protection and a firing platform for infantry squads. The Bradley Fighting Vehicle replaced most of the M 113 armored personnel carriers in the heavy divisions during the 1980's. The Bradley was not specifically designed as an air defense weapon. Air defense was to be provided, in part, by the PIVAD gun.

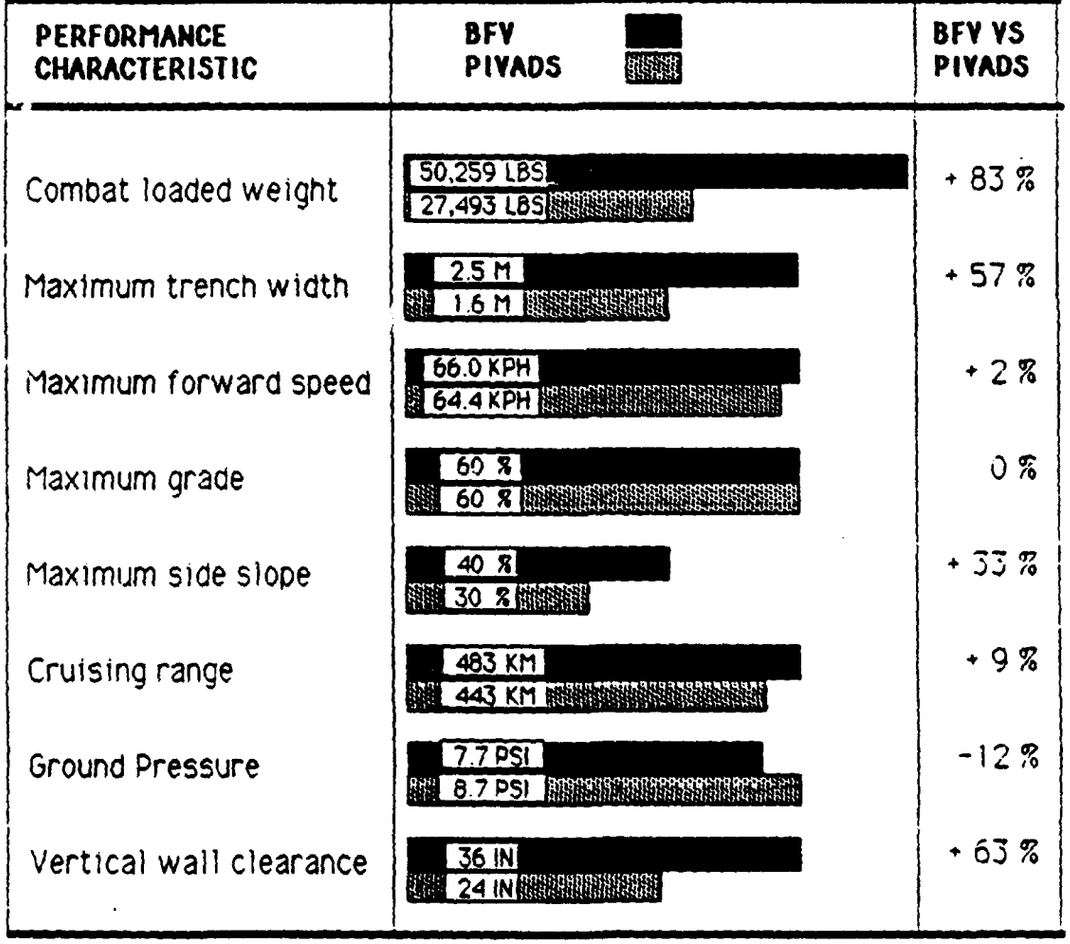
The PIVAD uses a modified M 113 (designated the M 741) tracked chassis. The M 741 transports the M 168 (Vulcan) high-speed cannon system, a basic load of ammunition, a crew of three of four service members and their personal equipment. It was originally developed in the late 1950's and was fielded during the Vietnam conflict. A comparison of several technical characteristics between the more modern BFV and the older PIVAD system is informative and is outlined in figure 1.

Figure 1 depicts the relative advantages/disadvantages in several key aspects of mobility. The BFV is designed to keep pace with the M-1 Abrams tank. If the BFV were to replace the PIVADS, obviously SHORAD units using the BFV would be able to keep pace with M-1's and other BFV's. This compatibility of maneuverability is essential for SHORAD units to be able to accomplish their mission of providing freedom of maneuver to forward units.

One key aspect of maneuverability is cross country speeds, which are a function of cross country terrain. In this regard, the parameters outlined in Figure 1 are revealing. Although both the PIVADS and BFV have similar maximum forward speeds[16], such

factors as maximum trench width[17], vertical wall clearance[18] and maximum side slope[19] play heavily when moving cross country. The side slope characteristic is especially important. Air defense units work in and around hills and slopes in order to provide overwatch fires on likely avenues of enemy air approaches. Figure 1 clearly depicts an advantage to the BFV over the PIVADS in all of these areas.

FIGURE 1 - PERFORMANCE CHARACTERISTICS - MANEUVER- LAND



One of the biggest drawbacks of the BFV is the weight factor. The data portrayed in figure 1 is for the M2A1 model. With the

fielding of the M2A2, the problem will be even more significant (M2A2 weight - 64,500 lbs). The PIVADS is much lighter, which makes it easier to transport and accessible to more bridges. In certain situations, this could be an important factor. Interestingly, however, the PIVADS has a higher ground pressure factor[20] than the BFV. In operating in torn-up and muddy terrain, the BFV would retain the advantage.

The increased weight contributes to another drawback. That is the requirement for fuel. Without fuel, there is no maneuver. The BFV will consume approximately 175 gallons of fuel to achieve its 483 mile cruising range. The situation will be worse with the M2A2. The PIVADS will use around 95 gallons to travel 443 miles. This equates to a 41% reduction in miles per gallon when converting to the BFV, with concomitant increases in logistical requirements for fuel and fuel transport.

Figure 1, however, does not tell the entire story. The biggest problem in maneuverability for air defense units arises during offensive operations, especially movements to contact. Air defense units attempt to provide covering fires for M-1's and BFV's during this offensive maneuver by keeping near the supported unit and using the "same movement techniques used by the supported unit"[21]. The objective is to keep within 400 meters of the lead elements.[22] Once contact with the enemy is made, however, the superior burst speed and much advanced suspension system found on the BFV[23] tends to leave supporting PIVAD units struggling to keep up. In anything except optimal terrain, they cannot.

Another aspect of maneuverability is water operations. Figure 2 compares performance characteristics in and around water. Water and river crossing operations are important in combined arms operations. Air defense doctrine calls for gun systems to cross water obstacles with the assault force.[24] Both vehicles have compatible fording depths[25] and wave height tolerance.[26] Neither system would be considered superior amphibious vehicles, but both are capable of performing river crossing operations. Essentially, the BFV and PIVADS have similar capabilities in and around water.

FIGURE 2 - PERFORMANCE CHARACTERISTICS - MANEUVER- WATER

PERFORMANCE CHARACTERISTIC	BFV / PIVADS	BFV VS PIVADS
Fording Depth	1.05 MTRS / 0.99 MTRS	+ 6 %
Swim speed	7.2 KPH / 6.4 KPH	+ 13 %
Maximum Wave Height	12 INCHES / 12 INCHES	+ 0 %

Each system has some technical advantages over the other. In total, however, the BFV provides SHORAD units with the best capability to perform their primary mission. Its dash speed, superior suspension system, and enhanced performance characteristics make the BFV superior in offensive operations and cross-country maneuver. It has similar capabilities in and around water. The heavier weight and percent increase in fuel consumption are detractors, but there is

no increase in vehicle density (4 BFVs replace 4 PIVADS) in the forward brigade. Actual fuel requirements would increase about 60 gallons of fuel per 100 kilometers of platoon operations. This should not present a formidable burden on forward supporting units.

NIGHT AND LIMITED VISIBILITY OPERATIONS

Night and limited visibility maneuvers are becoming more and more the norm in military operations. With the increased lethality and capabilities of modern weapons systems, being seen on the battlefield is extremely unhealthy. The use of night, fog, weather, and manufactured obscurants is virtually a necessity in modern warfare. With the rapid technological developments in night and obscured vision devices, the side that can most readily adapt and utilize decreased visibility conditions will have an inherent advantage. The M1 tank and BFV have sophisticated equipment in order to exploit this advantage. The PIVADS systems are somewhat lacking. Figure 3 highlights the equipment available to the two systems.

FIGURE 3 - LIMITED VISIBILITY AIDS - BFV VS. PIVADS

PIVADS	BFV
AN/PVS-5 NIGHT VISION GOGGLES - (1 ea)	AN/PVS-5 NIGHT VISION GOGGLES - (3 ea) AN/VVS-2 DRIVER'S NIGHT VIEWER - (1 ea) STABILIZED GUN SYTEM

The AN/PVS-5 night vision goggles are standard for both the PIVADS and the BFV. These are second generation night vision devices that will eventually be replaced by the more sophisticated, third generation, AN/PVS-7 goggles.[27] Both must be strapped to the user's face. Either will enhance any crew member's ability to operate effectively in reduced light conditions.

There are two major differences between the PIVADS and the BFV. One is the AN/VVS-2 driver's night viewer. It is a passive device found on the BFV that allows the operator to drive at night under blackout conditions or observe around the vehicle without opening the driver's hatch. It is portable yet, unlike the night vision goggles, it does not attach to the driver's face.[28] The other difference is the turret-stabilization device on the BFV. The gun can be directed towards a reference point, stabilized, then used as a navigational aid in limited visibility conditions.

The PIVAD has nothing remotely comparable to these two devices. This gives a clear advantage to the BFV when operating during night and limited visibility operations. The more modern BFV was designed to perform in this type of environment. The older PIVADS was not. Limitations in night and limited visibility operations impede the PIVADS crew from maneuvering with the force as part of a combined arms team. This several hampers their ability to perform the primary SHORAD mission of providing freedom of maneuver in the main battle area.

NEED FOR DEDICATED ADA UNITS TO ENSURE MANEUVER

If the BFV is adopted as the primary air defense gun system in the heavy division, then what is the need for dedicated air defense units operating in forward brigade areas? Why not just let the Bradley's in the maneuver units perform this mission themselves?

These are fair questions. Doctrinally, the BFV squad leader must know how to employ his system in an anti-aircraft role. To this end, there are tactics, techniques and procedures developed to accomplish this.[29] But the emphasis for the maneuver unit is not necessarily on air defense, and certainly it is not to provide air defense to other units operating in the brigade area. There is a critical need for deployed units, working well forward in the main battle area, monitoring the air defense early warning nets, and providing commanders the freedom to maneuver.

Dedicated air defense units in the brigade area have several missions. There are many elements, such as tactical operations centers (TOCs), logistical trains, artillery units, and bridging assets that have little or no organic air defense capability but are certainly important to the maneuver scheme in the brigade. Most of these elements would not be physically located under any dedicated air defense umbrella that forward maneuver elements could provide.

In the defense, the brigade rear area has a critical requirement for air defense units. Soviet doctrine realizes this. Their tactics warn that "when organizing penetration of such defenses it is important to foil or maximally hinder the enemy's maneuver, and chiefly achieve aerial envelopment of his forces".[30] An aerial envelopment landing in

the brigade rear is serious business, and it is to this purpose -- the protection of the commander's freedom of maneuver -- that air defense units are specifically employed. Many brigades retain control of their PIVAD platoons in the defense to facilitate air defense of critical assets in the rear area.

Dedicated air defense units are equally important in the offense. As combat units move forward, they must give up covered and concealed positions. These units become excellent targets for air interdiction by enemy aircraft. Air defense artillery units, dedicated to the third dimension of the battlefield, must be emplaced forward to provide overwatch air defense fires.

To accomplish overwatching fires, air defense units design their defense along the long axis of the supported moving formation.[31] They concentrate on the avenues of enemy air approach. These approaches may or may not correspond to the ground avenues of approach used by enemy forces (which are typically the focus on the friendly ground commander). SHORAD units must be able to maneuver to occupy air defense overwatch positions. Presently, in anything except ideal terrain conditions, the PIVADS cannot accomplish this mission.

Dedicated air defense units provide vital protection to critical assets important to the commander's scheme of maneuver. Whether heavy divisions are conducting offensive or defensive operations, there is an absolute necessity for these committed air defense units. Deployed well forward and focused on monitoring air operations in the main battle area, these units provide freedom of maneuver to high-value combat, combat support and combat service support assets.

SUMMARY

Overall, the PIVADS has serious limitations in the area of maneuver. It cannot keep up with the M1's and BFV's organic to heavy divisions when operating on anything except optimal cross-country terrain. Its limited burst speed diminishes its ability to furnish overwatch air defense fires for maneuver task forces. This restrains the the commander's ability to seize and maintain the initiative in offensive operations.

The PIVADS is outclassed when attempting to maneuver in night or limited visibility conditions. This is a serious handicap when considering that this is the exact mode that Army operations are emphasizing. As technologies evolve, this relative disadvantage will only get worse, not better.

The need for dedicated air defense units working in forward areas is obvious. There are many critical assets necessary to forward area operations that can apply only passive air defense measures for protection. Air defense units monitoring the air battle in forward areas are critical to the commander's scheme of maneuver and his maintaining of freedom of action.

In the next chapter I will discusses firepower. It is one of the primary components of combat power. But even the best firepower system is useless unless it can maneuver to be in the proper place in a timely manner in order to provide appropriate fires. Currently, as seen through the standpoint of maneuver, the PIVADS is not up to the task. It is not the better system in providing the commander with freedom of maneuver in the forward battle area.

CHAPTER 2 -- FIREPOWER

"In the Lam Son 719 operation in Vietnam, slightly more than 100 Army helicopters were lost in combat with roughly the same number of Army pilots and crewmen killed or missing in action and several hundred others wounded. The Air Force lost seven fighter-bombers, and four pilots were killed in action. ... (the) helicopters were operating against an extremely dense and effective low-altitude air defense gun system that had the advantage of being able to concentrate on the natural flight routes imposed by the mountainous terrain, especially in marginal weather."[32]

A primary mission of SHORAD units is to deny sanctuary to enemy aviation elements. The role of firepower is to suppress, disrupt, delay or destroy the enemy.[33] During the Vietnam war, the Vietnamese dedicated a tremendous amount of firepower attempting to deny U.S. forces sanctuary in their area of operations. Over 2500 fixed and rotary wing aircraft were lost in Vietnam due primarily to gun fire.[34] As the above examples show, firepower is a very effective means of accomplishing the air defense mission.

Three categories of firepower will be discussed in this chapter. The first compares technical capabilities of firepower such as maximum effective range, volume of fire, and the ability to fire on the move. Next, each system's ability to fire during limited visibility will be discussed. Finally, the chapter will examine the debate of the viability of a gun system versus known threats to U. S. Army heavy divisions.

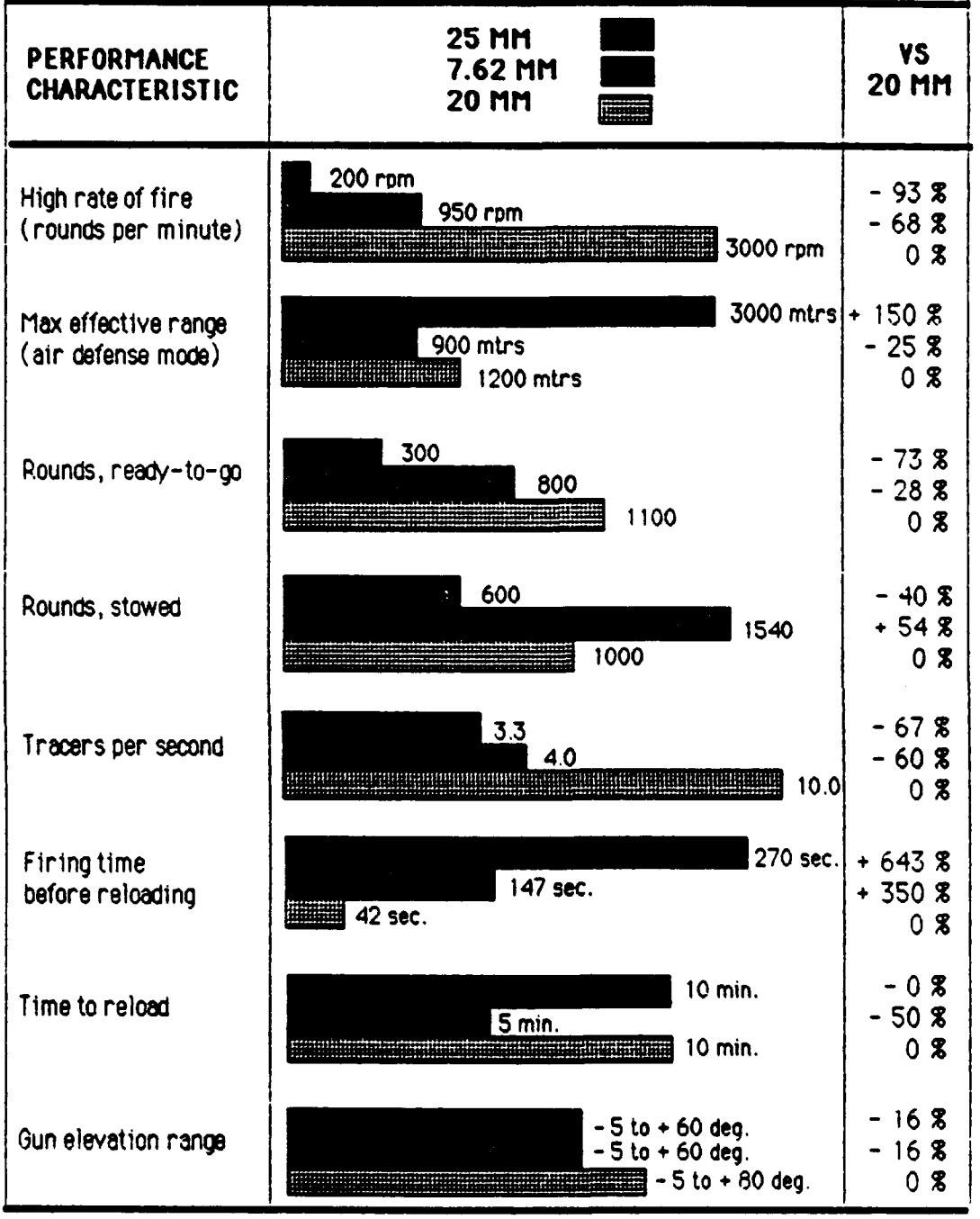
PERFORMANCE CHARACTERISTICS - FIREPOWER

The BFV employs three different types of weapons systems. They are the 25 mm chaingun, the 7.62 mm coax machine gun and the TOW missile system. Each of these systems could conceivably be utilized in the anti-air role. The PIVADS employs the M 168, 20 mm cannon assisted by an on-board range-only radar. The PIVADS also carries two Stinger air defense missiles. This section will only discuss the relative performance characteristics of the on-board gun systems. Missile systems will not be reviewed in this monograph.

Performance characteristics of the three gun systems are depicted in Figure 4.[35] This figure shows mixed results when attempting to compare the two weapon systems in the area of firepower. The most notable advantage of the PIVADS over the BFV is in the volume of fire. Volume of fire is extremely important and is "the key to active air defense against attacking aircraft".[36] This deficiency must be addressed when considering an interim replacement. One possible short term solution would be to "beef up" the ammunition feed servo motors on the BFV and increase the capacity on the feed select solenoid. Any boost would, of course, change several of the other BFV firepower performance characteristics discussed below.[37]

Another advantage of the PIVADS is the suppressive effect. Suppressive effect here is measured by the tracers per second flying past the enemy aircraft. The High Explosive Incendiary with Tracer Self-destroying (HEI-SD), fired in the air defense role by the PIVADS, sends about 10 tracer rounds per second down range. The High

FIGURE 4 - PERFORMANCE CHARACTERISTICS - FIREPOWER



Explosive Incendiary fired by the BFV fires about one-third that amount. For an air defense system to be effective, it does not necessarily have to hit or destroy a target. If SHORAD units can

suppress the enemy and deter him from performing his mission, they are effective.[38].

The final PIVADS firepower advantage discussed here is the gun elevation range. The majority of targets engaged by a gun system would be near or below the skyline. This would especially be true at the increased distances that the Bradley could engage a target. Still, gun elevation is an important consideration for an air defense weapon. This BFV limitation may be expensive to correct through engineering. Individual fire units might be required to overcome the problem by clever siting -- such as elevating the nose of the carrier on a slope or a log. These factors would be METT-T dependent, and this limitation of the BFV is probably not insuperable.

The BFV also has some advantages. The most prevalent is a substantial increase in the maximum effective range of its 25 mm gun over the 20 mm PIVADS. This is absolutely critical. The 20 mm gun system just does not have sufficient range to adequately accomplish its mission. This is because air defense doctrine calls for considering an ordnance release line when designing a defense.[39] For most "dumb" munitions, this is about 500 to 1500 meters from the target area.[40] It is highly desirable to engage and suppress enemy aircraft prior to ordnance release. As enemy delivery systems become more sophisticated, the ordnance release point moves farther and farther from the target area. This is especially true of smart munitions. ADA weapons must overcome this distance factor by either extending their range and/or displacing further from the defended unit. The BFV, with its increased reach, contributes towards solving this dilemma. In today's combat environment, 3000 meters may still be inadequate. As

we will see in chapter 3, however, it is a remarkable improvement over the PIVADS system.

Another Bradley advantage is the firing time before reloading. At its decreased rate of fire, the Bradley would fire longer between reloads. This is especially pronounced when both gun systems on the BFV are added together. Then, the Bradley has almost seven minutes of uploaded or stowed ammunition. This represents an almost 10 fold increase in ready-to-go ammunition over the PIVADS system. Reloading has always been a critical limitation for PIVADS.[41] In the self-propelled version (as with the BFV), the system must be brought "off line" while reloading is effected.

Not reflected in figure 4 is the stabilized gun turret on the Bradley. There is nothing that prohibits the PIVADS from firing while on the move, but its lack of stabilization renders its accuracy to little more than suppressive fires.[42] In practice, firing on the move could only be done in optimal terrain. Finally, the PIVADS system has the advantage of an on-board range-only radar. Its primary purpose is to provide automatic lead angle and super-elevation to the gun. It is specifically designed to overcome a human factors problem of tracking a crossing, high-performance aircraft. The BFV would have no such radar and would be at a relative disadvantage. In the absence of this technology, only gunner practice and experience can overcome this problem.

All in all, each system has some advantages over the other. Without doubt, at targets within 1200 meters, the PIVADS, with its high volume of fire and radar assisted gun is the better system. But most targets are attempting to make maximum use of their ever

increasing stand-off capabilities. At distances over 1200 meters, in engagements requiring more than 20 seconds of firing and during operations requiring movement, the Bradley is clearly superior. Any interim measure to increase firing volume would further tip the scales in favor of the Bradley.

NIGHT AND LIMITED VISIBILITY OPERATIONS

As was discussed in chapter one, night and limited visibility military operations are becoming more frequent. Therefore, the effective use of firepower during these timeframes is becoming relatively more important.

As with maneuver, the BFV has sophisticated equipment in order to exploit night and limited visibility operations. Again, the PIVADS systems are somewhat lacking. Figure 5 highlights the equipment available to the two systems.

FIGURE 5 - LIMITED VISIBILITY AIDS - BFV VS. PIVADS

PIVADS	BFV
AN/TVS-5 NIGHT SIGHT (1 ea)	INTEGRATED SIGHT UNIT (ISU)

The AN/TVS-5 night sight is a first generation night vision device that mounts on the M-168 20-mm cannon. It has a single eyepiece and requires the gunner to maintain his position with his eye socket against the sight reticule. It has virtually no capability to see

through fog, smoke, or other manufactured obscurants. It is also highly susceptible to blooming -- a situation where too much light overpowers early model night vision devices and renders them temporarily useless [43]

The Bradley's Integrated Sight Unit (ISU) is truly a quantum leap in technology over the AN/TVS-5. During limited visibility operations, it will utilize its thermal-imagery capability to acquire targets. Once a target is acquired, the image can be magnified (12X) for engagement. Although rain and snow will degrade the range of the thermal sights, they are still capable of penetrating fog, smoke, camouflage, and light vegetation.[44] The PIVADS has nothing comparable to the thermal sights. This severely limits the SHORAD crew's ability to provide firepower and deny sanctuary to enemy aircraft during limited visibility operations.

DOES A GUN SYSTEM HAVE A ROLE?

The currently projected replacement for the PIVADS is the LOS-F-H. The initial fielded version of this system employs only missile systems, no air defense guns. One question comes quickly to mind. Is there a role for a gun system in the heavy division?

This question has been discussed frequently within the air defense community since the cancellation of the Sergeant York Air Defense Gun in 1984.[45] The SGT York was supposed to replace PIVADS as part of the Division 86 changes. The design concept called for a system to keep pace with the M-1 and BFV while providing increased crew protection from indirect and small arms fire. But, as

much as anything else, the SGT York was cancelled because it was unable to defeat the primary air threat to front line maneuver units -- attack helicopters.[46]

The SGT York had a maximum effective range of 4000 meters[47]. Certainly this was an enhancement over the PIVADS. But, with the stand-off munitions of the threat increasing in range, the huge investment in a gun system and associated acquisition equipment just did not warrant such an incremental increase in capability.[48] Therefore, what role will the BFV play, especially considering its maximum effective range is less than the design specification of the SGT York?

Its first role may be that of an interim cost-saving measure. The expenses associated with maintaining PIVAD specific equipment, maintenance personnel, ammunition and logistical overhead may outweigh any possible increased fielding and operating costs of the BFV -- especially since the BFV's are already fielded. That type of analysis is outside the scope of this monograph, but certainly is an area that must be explored.

Second, due to its lack of radar and IFF capability, a maximum effective range of 3000 meters is comparable to the maximum range that visual identification of aircraft can be effected. An increase in range over 3000 meters would be of marginal utility without a concomitant investment in more sophisticated acquisition and identification equipment. Therefore, the role of the BFV would merely be to fill the gap between the present day technical capability of the PIVADS and the SHORAD crewman's human capacity for visual target identification.

Finally, like the PIVADS, the BFV will have a secondary ground-to-ground mission. Maneuver commanders tend to understand gun systems and are more comfortable with their employment.[49] We will develop this role more fully in chapter 4. Suffice to say, however, with its full array of TOW's and machine guns, the Bradley would represent a substantial increase over the PIVADS in lethality against ground targets (especially armor) in the main battle area.

SUMMARY

The firepower comparison shows pluses and minuses for both systems. At shorter ranges, the PIVADS displays distinct advantages in volume of fire and suppressive effect. At longer distances, the BFV with its superior maximum effective range is more impressive. With technology pushing ordnance release points farther and farther away from the target area, the suitability of the shorter range air defense systems decreases.

The BFV is clearly superior in night and limited visibility operations. Its ability to acquire targets with its thermal sights is imperative on today's high technology battlefield. Today's systems must be able to defeat the degrading effects of weather, light vegetation and manufactured obscurants in order to continually deny sanctuary to enemy air forces.

The gun system still has a viable role in today's environment. The BFV is off-the-shelf technology. It has a standardized support structure organic to heavy divisions. An analysis should be conducted to determine the cost effectiveness of keeping the 20 mm system and

its associated overhead in the active force structure. Also, the BFV may fill the present gap between the maximum effective range of the PIVADS and the maximum visual target identification range of an air defense gunner. Lastly, like the PIVADS, it can be effectively utilized in its secondary role as a ground support weapon.

In the final analysis, there are a multitude of firepower factors which must be considered when reviewing a possible PIVAD/BFV substitution. The situation is obviously complicated by the fact that the BFV was not designed specifically as an air defense gun system. As noted in this chapter, some engineering changes may have to be considered in order to increase the BFV's deficiencies in volume of fire and suppressive effect. The next chapter discusses protection. Perhaps a view comparing the ability of the two systems to protect the force will be more distinguishing and, therefore, of more utility.

CHAPTER 3 -- PROTECTION

During the 1973 Arab-Isreali War, the Egyptians employed a mix of gun and missile systems around their Nile Delta airfields. Guns were utilized to complement the missile systems and cover missile dead zones. This proved to be a most effective combination. Unlike the 1967 conflict, Egyptian airfields were only breached and nullified by ground maneuver forces. Over one-third of all aircraft losses during the entire war were attributed to air defense gun systems. [50]

Protection is the conservation of the fighting potential of a force so that it can be applied at the decisive time and place.[51] The Egyptians had learned a hard lesson in the 1967 War when they failed to adequately protect their aerial forces from air attack. In 1973, air defense systems ensured the protection of these valuable assets. In this chapter, protecting the force will be discussed in two contexts. First, is the comparison of the protection to air defense elements from direct and indirect fires provided by each weapon system. Second, is the protection provided by either of the systems to the supported maneuver units.

PROTECTION FOR ADA UNITS

The PIVADS has several problems when it comes to self-protection. As with most systems, a problem in one area tends to compound problems in another. Shortcomings in maneuver and certain limitations in firepower (especially range) that have been previously discussed certainly contribute to the vulnerabilities of

PIVADS. This section will highlight four major problems: the PIVADS priority as an enemy Suppression of Enemy Air Defense (SEAD) target, its lack of standoff capability with concomitant necessity to work well forward in the main battle area, its lack of armor protection, and its inability to generate smoke.

There are two schools of thought concerning the PIVADS as a threat SEAD target. The preponderant view is that PIVADS will be a primary target in enemy offensive operations. Soviet tactical literature espouses the need to "disrupt the antitank, antipersonnel and antiaircraft fire plan" in the opening moments of battle.[52] The other view is that the PIVADS system has such limited range capabilities that the Soviet does not perceive it as a viable threat. No threat implies no priority in targeting (although finding them does imply the presence of a high value target in the vicinity). Ironically, if the second view is true, the greatest possible chance for survival of the PIVAD system may be due to its ineffectiveness in performing its primary mission.

If the PIVADS misses the wrath of the SEAD effort, there is more to come. Soviet doctrine calls for "continuous, powerful artillery fire and air strikes on troops in the enemy's first echelon".[53] For the PIVADS to perform its primary missions of protecting the force and denying the enemy sanctuary in the main battle area, it must be placed well forward in the first echelon. Offensive doctrine calls for PIVADS units to follow within 400 meters of forward elements.

The armor shielding of the PIVAD's M741 tracked vehicle affords some protection against indirect fire and small arms fire up to about 7.62 mm.[54] While better than nothing, it is not sufficient to

defeat the 12.7 mm machine gun. This gun is the Soviet standard mounted on virtually all Soviet assault helicopters and has a maximum effective range of 1500 meters.[55] The BFV was designed to protect against ordnance up to 14.5 mm[56] with upgrades to 30 mm with the M2A2 models.[57] These upgrades would represent a significant increase in protection for air defense crews employed on the battlefield.

Finally, the BFV has a significant smoke generating capability. With sufficient quantities of the proper type of diesel fuel, the BFV can generate an unlimited amount of smoke through the exhaust manifold.[58] Additionally, the BFV is equipped with the M257 smoke-grenade launcher. It has eight launcher tubes. Within six seconds, it can create a seven meter high by 70 meter wide smoke screen 20 to 50 meters in front of the vehicle that lasts from one to three minutes.[59] The PIVAD has nothing comparable to either of these capabilities.

Survivability is extremely important. Smoke keeps you from being seen. Armor protection keeps you from being killed. The BFV is clearly superior in self and crew protection. This becomes especially important for a potential priority target working well forward in the main battle area.

PROTECTION PROVIDED BY AIR DEFENSE UNITS

The words "air defense" imply protection of the force. We have already discussed the BFV's improved capability to provide freedom of maneuver due to its enhanced maneuverability characteristics. We

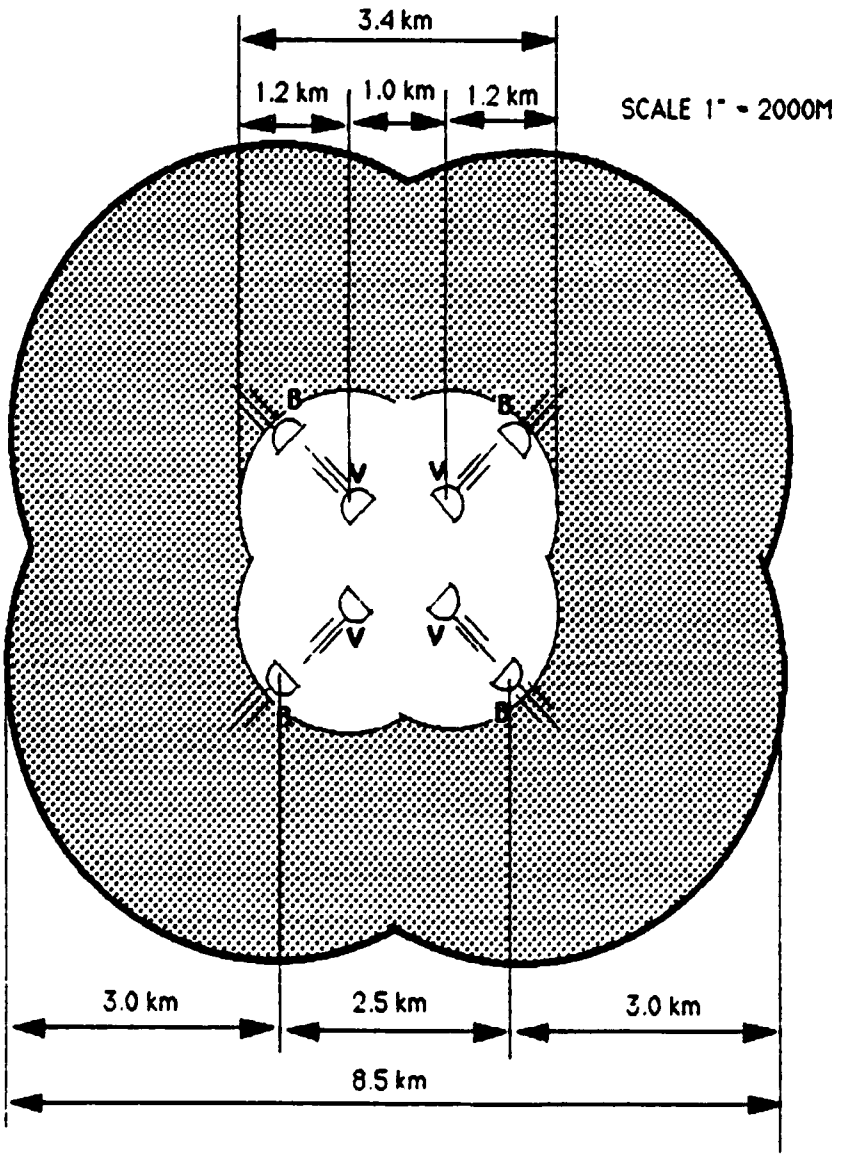
have also concluded that the BFV's largest contribution in denying the enemy sanctuary through firepower is its vastly increased maximum effective range. How exactly does this correlate to increased protection of supported units in the main battle area?

To analyze this increased protection, we must look at a comparison between the two systems. We will inspect three doctrinal templates showing the employment of two platoons of four systems each. One will be of a point defense, such as a TOC or an artillery battery, which is a typical PIVAD platoon mission when supporting a task force in the defense. Another will be of a convoy on the move. The third will be of an offensive operation, providing air defense for a leading company team on a bounding overwatch. For purposes of comparison, the templates will show the platoons employed in optimal terrain under optimal conditions.

Figure 6 is a layout of a typical point defense. Air defense doctrine calls for PIVADS emplacement to be no more than 1000 meters apart, or five-sixths of the systems maximum effective range. This is to comply with the principle of mutual support.[60] Mutual support is important to SHORAD units to ensure coverage of dead zones. Using the "five-sixths rule", the maximum mutual supporting distance for the BFV would be 2500 meters.[61] As seen in figure 6, the area of coverage provided by the BFV is significantly greater than the PIVADS.

There are two mathematical relationships that contribute to this effect. First, since the weapon system emplacement distances are two and one-half times greater for the BFV than the PIVADS, the emplacement point away from the protected asset can be significantly

FIGURE 6 - DOCTRINAL TEMPLATE - POINT DEFENSE



increased with the BFV. This contributes to another principle of air defense employment -- early engagement.

The second relationship is the area of coverage provided by the BFV. It is increased by the square of the maximum effective range.

In figure 6, the total area coverage provided by the PIVADS platoon is approximately 10.2 square kilometers, of which approximately 7.9 square kilometers are covered by multiple systems. The BFV platoon provides coverage to approximately 63.5 square kilometers, with 49.5 square kilometers receiving multiple coverage.

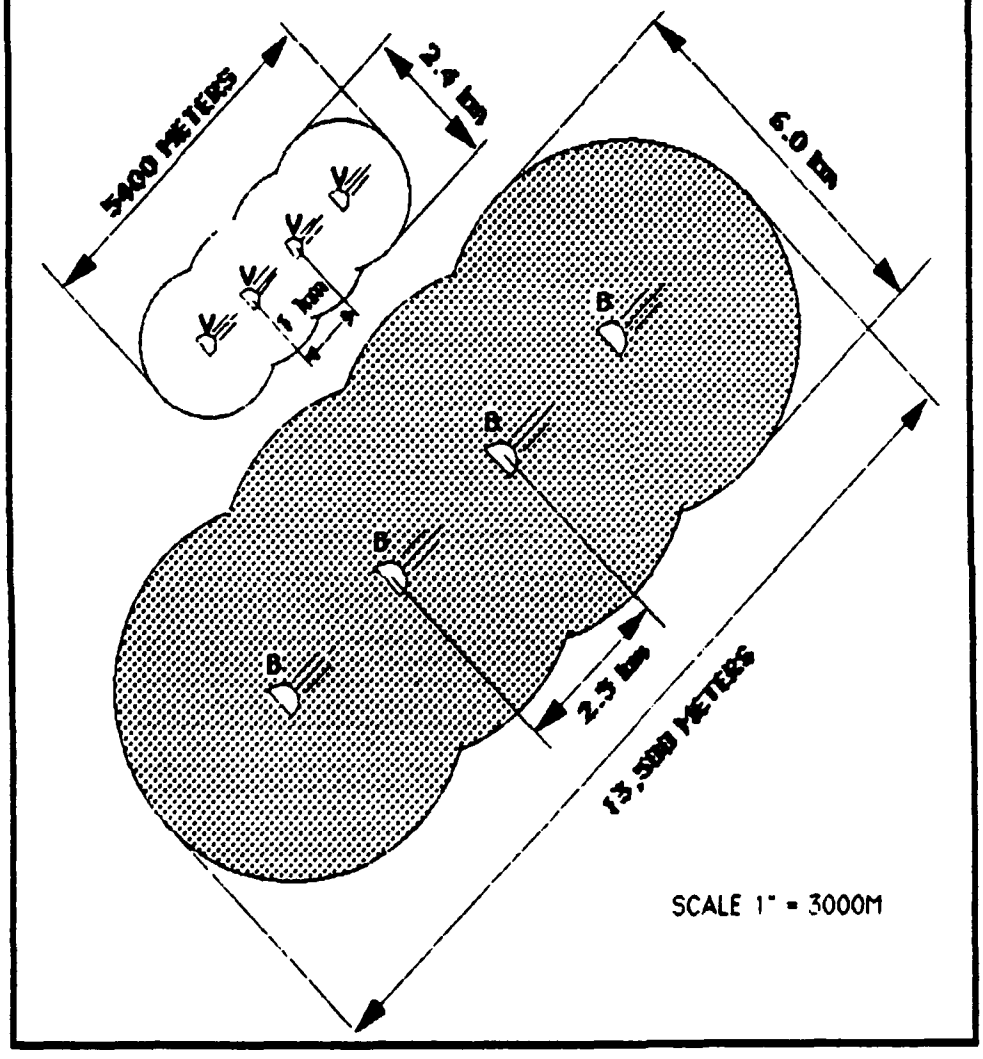
Interestingly, the BFV platoon can provide mutual support while defending a task force front in the defense. In most instances, the PIVADS platoon cannot. The PIVADS platoon is frequently assigned in direct support to a battalion-sized task force. The task force is expected to defend against a regimental size unit.[62] A typical task force front in the defense is from 3 to 8 kilometers.[63] A BFV platoon providing a point defense in a task force sector achieves a 8.5 KM front. The PIVADS platoon achieves only a 3.4 KM front. Obviously, these figures represent emplacement in optimal terrain under optimal conditions. Graphically, they depict a significant increase in protection capability of the BFV over the PIVADS.

Figure 7 depicts another typical PIVAD mission. PIVADS, as discussed previously, have a limited ability to shoot-on-the-move. Doctrinally, they are interspersed and move at about 1000 meter intervals in providing convoy air defense coverage.[64] As with the point defense, this is to provide mutual support between fire units.

Again, using the five-sixths rule, figure 7 portrays a BFV platoon performing the same mission. To conserve combat power and facilitate command and control during movement, tank and mechanized infantry battalions often plan to move on one route.[65] These columns consist of between 180 to 220 vehicles moving in nine or ten march units (including trains and attached units). Total length

will be about 20 kilometers. Neither the PIVADS nor the BFV can provide adequate security for a column of this length.

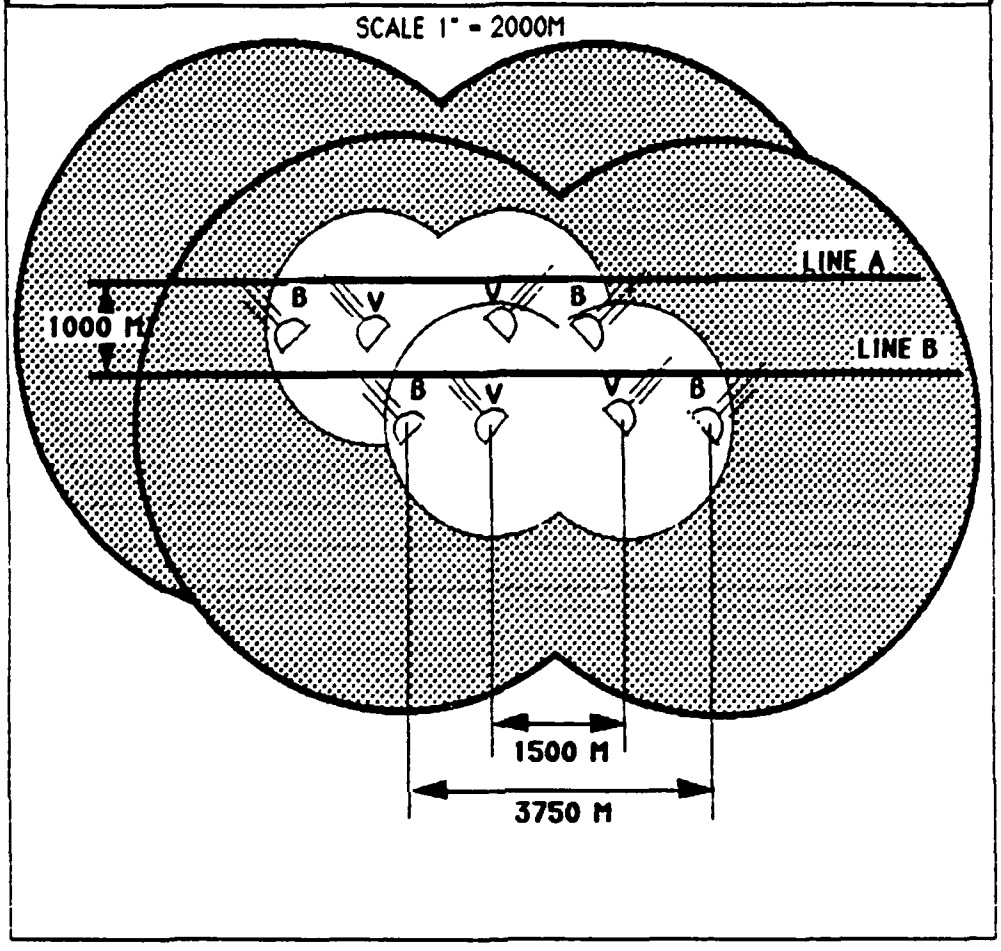
FIGURE 7 - DOCTRINAL TEMPLATE - CONVOY



The BFV, however, provides a significant improvement over the PIVADS in both longitudinal and latitudinal coverage.

Figure 8 introduces the concept of overlapping fires. Many times, especially during movements in the offense, mutual support just cannot be achieved. Not all dead zones can be covered. During a

FIGURE 8 - DOCTRINAL TEMPLATE - MOVE TO CONTACT



bounding overwatch maneuver, PIVAD fire units can work in teams of two. To facilitate overlapping fires, units attempt to maintain a maximum of 1500 meters between the two fire units. This distance equates to 125% of the maximum effective range of the PIVAD system versus the five-sixths distance used for mutual support. Overlapping fires do not provide the same protection as mutual support, but they do decrease the possibility of gaps in the air defense coverage.

In the offensive, SHORAD units should be positioned to provide overwatching fires with priority towards high speed enemy air corridors in the task force sector. The objective is to keep PIVAD

systems within 400 meters of the forward elements. This allows 800 meters, or two thirds of the PIVAD maximum effective range, to extend in front of the protected units.

Figure 8 depicts a platoon providing overwatch fires employing overlapping fires at the maximum recommended range. Line A represents the maneuver unit and line B represents the overwatch unit. In this example, line B is 1000 meters behind line A. The two PIVADS and two BFVs are positioned 400 meters behind each line. The two PIVAD's behind each line are separated by 1500 meters and the two BFV's are separated by 3750 meters.

At these distances the systems, working in pairs, can provide overlapping fires but not mutual support. The PIVAD systems behind line B can provide air defense for the overwatching unit on line B, but little support to the front or on the flanks for the maneuver units in front of line A. The BFV's, however, provide fire support for the front and the flanks of both the overwatch and the maneuver unit. In fact, in favorable terrain, one BFV with the overwatch unit located behind line B provides more fire support to the maneuver unit on line A than two PIVAD units located behind directly behind it!

SUMMARY

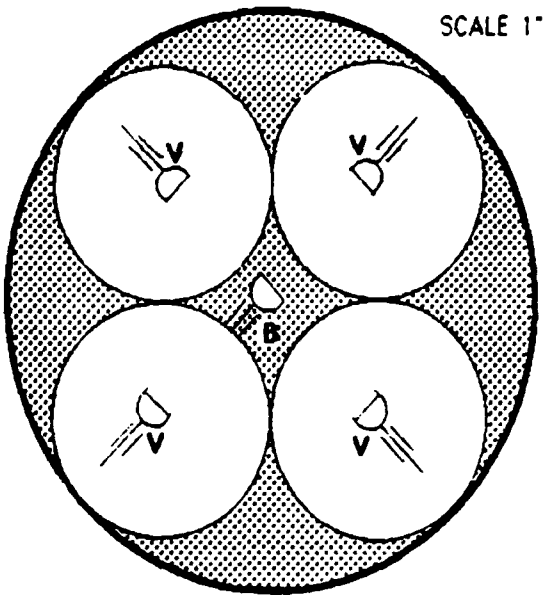
The BFV is superior in almost every aspect of protection for SHORAD crews. The BFV cannot be distinguished as an air defense weapon and therefore should receive no special SEAD targeting effort. Its extended range allows for greater stand-off distances (dispersion) from protected assets. Its armor protection is superior and

specifically designed to protect the SHORAD crews from the primary threat weapon systems that will be employed against it.

Of equal importance is the superior protection provided to supported units. The BFV does not specifically identify high value targets. It has no radar signature. In virtually all of the customary roles, the BFV, with its enhanced maximum effective range, provides greater area coverage than the PIVAD systems.

An interesting comparison is of one BFV to a platoon of four PIVAD systems. One BFV can provide over 28 square kilometers of

FIGURE 9 - ONE BFV VS PIVAD PLATOON - AREA COVERAGE



TOTAL AREA OF ONE BFV = 28.3 SQUARE KM

TOTAL AREA OF PIVAD PLATOON = 18.1 SQUARE KM

coverage in optimal terrain (see Figure 9). This is over one and one-half times more area coverage than the cumulative area protection provided by an entire platoon of four PIVADS weapons systems.

As discussed in previous chapters, the issues of range, cross-country speed, maneuverability and stabilized firing platforms come again to the fore when analyzing the ability of the PIVAD to perform its SHORAD mission of protecting the force. Typically, one PIVAD limitation compounds another. Except for some limited aspects of firepower, it falls short in all of the dynamics of combat power discussed thus far. PIVADS needs a true multiplier to overcome its apparent deficiencies. Leadership, the only remaining dynamic, must play a formidable role if the PIVAD is to overcome presently considered shortcomings.

CHAPTER 4 -- LEADERSHIP

On the evening of 19 December, 1989, President George Bush ordered U.S. combat troops into Operation Just Cause in Panama. Panama's 40 threat aircraft were quickly captured or dismantled. Without a viable air threat, towed Vulcan units of the 7th Infantry Division and the 82nd Airborne Division were called upon to perform in their secondary ground support role. Before daylight, these Vulcan units had fired over 1400 rounds of ammunition at ground targets and naval gunships.[66]

Leadership is the glue that binds and the lubricant that moves men and equipment. Just like in Operation Just Cause, it is the duty of leadership to effectively combine the available maneuver, firepower and protection in various situations found on the battlefield in order to accomplish the mission.[67] Brigadier General Wass de Czege, in his analytical framework, deems leadership to be the most important element of combat power.[68] Leadership truly may be a combat force multiplier.

Is there a role for leadership when making a comparison between two weapons systems? Definitely. In fact, the leadership role may be more important than all of the other dynamics of combat power -- maneuver, firepower and protection -- combined. This premise is based on the fact that leadership has the greatest impact on the moral (or human) aspect of battle.

This chapter will place less emphasis on the technical comparisons of the two systems. The dynamics developed thus far will be analyzed through the prism of leadership. There are numerous human elements which should be considered when either introducing new systems or

retaining old systems within the force. What are the projected effects of battle on soldiers, units and leaders when utilizing the two systems? This is the question that we will address in this chapter.

EFFECTS ON SOLDIERS

There are currently over 2700 soldiers in the active force with the 16R, PIVADS crewman, military occupational specialty (MOS) designation. These soldiers represent over 17,000 man-years of experience in the combined arms employment of SHORAD weapons systems in maneuver units.[69] This amount of experience base is both an asset and a liability when considering a change in major weapons systems.

The group is an asset because it represents a highly qualified group of soldiers, already in the force structure, who are familiar with SHORAD tactics, techniques and procedures (TTPs) in general and PIVADS weapon system employment in particular. If a change is made to the BFV, many of the TTP concepts (if not the TTPs themselves) will remain unchanged. The fundamental missions of SHORAD units, the basic objectives of air defense, and the concentration on the aerial threat remains constant.

But the group also represents a liability. The transition to the BFV will not not happen overnight. Many problems in training and equipment will arise. In particular, there must be a complete revamp of the mindset which has tended to accept the limitations of the present PIVAD system and "make due as best one can".

PIVAD system soldiers will now be asked to man an entirely new array of systems. When the infantry branch progressed through this process in the early 1980's, several shortcomings were highlighted and addressed.[70] These included span of control problems for the BFV squad and platoon leader, work/rest schedule priorities, problems of ammunition reload, proficiency of thermal sight operation, and a tendency of infantry units to attempt to fight like armor.[71] There is little reason to believe that PIVAD crewmen will not be confronted with these and other problems.

In particular, what will be expected of the SHORAD crewman who now has limited capability to fire and maneuver at night and during limited visibility? Heretofore, he simply did the best he could while both he and the supported unit leadership "lived" with these limitations. With the BFV and its thermal sight, he can now detect and classify objects as aircraft at night and during limited visibility operations. Through improved technology or possibly enhanced training, BFV air defenders may be able to recognize and even identify such aircraft using the thermal sight.[72] This will have considerable implications on crew training, size, duties, and operations.

There is also the problem of auxiliary weapons systems and associated targeting and fire control. The PIVAD crew already carries a basic load of Stinger missiles. These should follow with the BFV. Also with the BFV, crews would have an antiarmor capability using the TOW missile system and the 25 mm gun using the armor piercing discarding sabot - tracer (APDS-T) round. All of these complicate the level of training required for soldiers working in the MOS.

The caliber of soldier must be superior. Recruiting, training, and maintaining this capacity has repercussions throughout the personnel life-cycle process. If the soldier quality required to operate the LOS-F-H system is significantly higher than the present 16R population, then efforts should begin now to screen, acquire and mature the necessary enlisted force. Fielding the BFV now would expedite this essential long-term transition to a higher caliber soldier.

The effects on soldiers are many and varied. But air defense soldiers ultimately fight as members of air defense units. These units deploy with other units in the combined arms team to accomplish the overall goals of the maneuver commander. Whether the choice for future air defense is the BFV or the PIVADS, the effect on units must be analyzed.

EFFECTS ON UNITS

If the adoption of the Bradley fighting vehicle comes to pass, there will be an enormous impact on both supported and supporting units of air defense organizations -- as well as the air defense units themselves. The new characteristics present with the BFV must be understood and integrated into tactics, plans, and day-to-day operations of all sorts.

One of the strongest arguments (outside its enhanced capabilities as detailed in earlier chapters) for the adoption of the BFV as an interim measure is the fact that it allows SHORAD units to get a headstart on working in and around the Bradley chassis. As stated in the introduction, the LOS-F-H system is mounted on the Bradley

chassis. Gearing up the maintenance and support facilities for Bradley service would start sooner. Reducing PIVAD specific maintenance personnel, test equipment, and overhead structure in the heavy division could be expedited.

The air defense base structure would need to adjust quickly. Implications on doctrine are many and would need analysis. Air defense units would confront a wider array of combat scenarios. New concepts on the command and control of missile, gun and antitank systems would need development. Integration of the systems with other units on the battlefield would need refinement. All of these require time and effort and early adoption of the BFV would be desirable.

Finally, the adoption of the BFV as the primary air defense gun system in the heavy division should have residual benefits for mechanized infantry units for as long as the Bradley remains in the arsenal. Air defense units would be dedicated to solving or overcoming any limitations of the BFV when employed by mechanized infantry in the air defense role. One would expect many refinements of air defense tactics, techniques and procedures which could be utilized by mechanized infantry units when BFV air defense units were not present or available.

Accepting the status quo would perpetuate the known limitations of the PIVAD units presently in the structure. Adopting the BFV would jumpstart the process of changing over to the Bradley chassis with all the implications on concomitant support structures, equipment and personnel. All are effects on units. Ultimately, they are also effects on leaders.

EFFECTS ... LEADERS

The most important impact on leaders with the adoption of the BFV is that commanders at all levels would have a greater ability to apply the imperatives of AirLand battle --synchronization, depth, initiative and agility -- to the battlefield.

Improved synchronization comes about because the BFV is a more advanced system than the PIVADS. As outlined in the first three chapters, it is better able to assure the commander freedom of maneuver, deny the enemy sanctuary in the forward battle areas, and protect his force. This being the case, the BFV provides a more-capable, dedicated battlefield operating system committed to reducing the commander's vulnerability to air attack. This reduces or eliminates many obstacles that present day maneuver commanders must consider when attempting to synchronize their effort.

The BFV allows the commander to use his initiative. In this regard, one of the biggest challenges facing the maneuver commander may be the need to accept the BFV as primarily an air defense system -- not a ground support system. This situation is not unknown to current air defense leaders, especially at the platoon and company level. Maneuver commanders, aware of the limitations of the PIVADS as an air defense weapon, tend to focus the PIVAD system more towards its secondary, ground-support role. This is understandable because the system provides a lot of firepower in this mode. There is no reason to believe that this situation will change, especially when a BFV air defense platoon -- utilizing a system originally designed as a ground assault weapon -- shows up in a task force commander's area

of operations. How will the maneuver commander employ it? It is his initiative to take; his call to make; his unit to employ; his asset to synchronize.

In the same light, with the Bradley ADA leaders would have a powerful new weapon system of multiple utility. This certainly would contribute to their agility. They need to be prepared to apply the system in other than its primary role. This is key. The history of warfare since the advent of air power has been the desire, if not outright need, to secure at least local air superiority. Once achieved, air defense assets can be expected to assume more and more of a ground support role. Adopting the BFV as a primary air defense weapon, with a secondary ground support role, will provide agility to the commander and help facility this change should it become necessary.

Finally, the BFV adds depth to the battlefield. All of the reasons mentioned thus far (increased ranges, greater displacement distances, ability to disperse, greater coverage areas, etc.) add to the extension of operations in time, space and resources -- and each makes a corresponding demand on leadership to remain master of these ever increasing dimensions in size and scope.

CONCLUSIONS

The difficulty of providing ground-based air defenses was predicted by early air power theorists. Yet the utility of such systems has been proven in virtually every war since the introduction of combat aircraft to the battlefield. The systems needed to fulfill the missions contemplated by the concept development community are expensive, complex, and require a long time to develop, test and field. If the LOS-F-H is deployed as presently scheduled, the PIVAD system will have served in the inventory for over 30 years. This is just too long. PIVADS system capabilities are simply inadequate to meet many of the required tasks

As outlined in chapter one, the PIVADS system cannot keep pace with the M-1 tanks and other BFV's found in the heavy divisions. Therefore, it cannot provide the requisite freedom of maneuver to allow the commander to maintain the initiative. This is a primary mission of SHORAD units. The PIVAD fails.

In chapter two, the PIVADS established a firepower advantage over the BFV when engaging targets for a short duration within 1200 meters. In other parameters of technical comparison however, such as time between reload and maximum effective range, the BFV is clearly superior. Firepower is a mixed bag when making relative comparisons between the two systems. Both are gun systems and have some inherent advantages over missiles in many tactical roles. The question as to which can better effect the SHORAD mission of denying sanctuary to the enemy can only be answered in a situational context.

Chapter 3 compared protection. This match went unquestionably to the BFV. The BFV was superior in virtually all aspects of crew and self protection. It was also superior in supported unit protection -- due mostly to its enhanced ranges and its low signature as a high-value asset. However, this was purely a relative comparison. As the stand-off capability of enemy delivery systems increases, both systems become more inadequate -- the BFV only less so.

Perhaps most importantly however, chapter four concluded that the BFV provides the tactical leader with a more diverse and capable weapon's platform. The adoption of the BFV as the primary air defense system in the heavy division would be a formidable challenge to soldiers, units and leaders. Air defenders would need to become more integrated into the ground commander's scheme of maneuver in order to maximize their enhanced systems capabilities. Air defense and supported units would have to develop and refine the tactics, techniques and procedures of a dual anti-air/anti-armor mission capable organization. Leaders at all levels would need to think through the new characteristics of support that air defense units could bring to the battlefield.

There may very well be an excess of BFVs due to near-term force structure reductions. Before turning these systems over to reserve component mechanized infantry units, the idea of substituting the BFV for the PIVADS should be contemplated. If the substitution could be accomplished at little cost in resources and without detracting from the primary objective of fielding the Line of Sight - Forward - Heavy as soon as practical, the idea certainly has merit.

The Bradley Fighting Vehicle was not designed as an air defense system -- it may only happen to be better than the one we presently have. The follow-on to the Product Improved Vulcan Air Defense System has been 30 years in coming -- and it still has yet to show up. The Bradley is here now. Let's take advantage of its improved capabilities.

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[30] V.G. Reznichenko, "Soviet Union Tactics," JPRS Report, Volume I, 1987, p. 76.

[31] Field Manual 44-3, p. 6-22.

[32] "Guns versus Missiles", p. 15.

[33] Field Manual 100-5, p. 12.

[34] "Are ADA Guns Dead", p. 15.

[35] T M 9-2350-252-10-1, p. 1-8. and T M 9-2350-300-10, p. 1-1.

[36] U.S. Department of the Army, Bradley Fighting Vehicle Gunnery, Field Manual 23-1. (Washington, D.C.: U.S. Government Printing Office, 1987) p. 7-1.

[37] Obviously, an increase in the rate of fire to, say, 500 rpm (from 200 rpm) decreases the fire time before reloading from 270 seconds to 108 seconds.

[38] Field Manual 44-3, p. 1-1.

[39] Field Manual 44-3, p. 6-10.

[40] Field Manual 44-3, p. 2-16.

[41] Field Manual 44-3, p. 4-5.

[42] Field Manual 44-3, p. 4-5.

[43] "Image Intensification Technology", p. 7.

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